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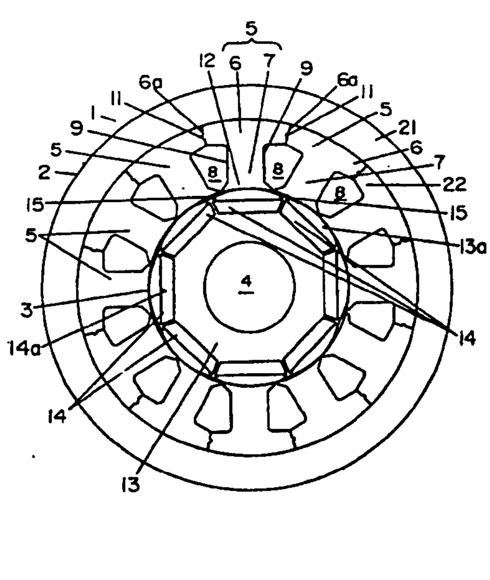
(54) **MOTOR**

(57) The invention relates to a motor comprising a stator core (22) having plural teeth (7) and slots (8) provided among the teeth (7), a winding (23) applied on the teeth (7) by a single turn, and a rotor (13) incorporating plural permanent magnets (14), which is rotated and driven by utilizing reluctance torque in addition to magnet torque. By turning thus divided teeth (7) by a single winding, the occupation rate of the winding in the slots (8) can be raised. As a result, a motor of small size and large output can be presented.

Fig. I



EP 0 823 771 A1

Description

TECHNICAL FIELD

The present invention relates to a synchronous motor comprising a stator for generating a rotary magnetic field, for rotating and driving by making use of a reluctance torque.

BACKGROUND ART

In a conventional general synchronous motor, a stator is formed by integrally projecting plural teeth from a ring-shaped yoke to its inner circumferential side. This stator is fabricated by laminating stator plates having plural teeth projecting to the inner circumferential side. It also comprises a stator core forming slots among these teeth, and windings are wound in these slots by distributed winding. The distributed winding is a winding method for winding distant teeth through slots. The rotor is composed by burying plural permanent magnets for magnetic poles in the outer circumference of the rotor core, and mounting a rotary shaft in the center.

In this way, by burying permanent magnets inside the rotor, the permanent magnet buried motor can utilize not only the magnet torque but also the reluctance torque, in which the reluctance torque is generated in addition to the magnet torque by the permanent magnets, as an inductance difference occurs between the inductance Ld in the direction of d-axis which is a direction for coupling the center of permanent magnet and the rotor center, and the inductance Lq in the direction of q-axis which is a direction rotated 90 degrees of electrical angle from d-axis. This relation is shown in formula (1).

$$T = Pn\{\psi a \times Iq + 1/2(Ld - Lq) \times Id \times Iq\} \quad (1)$$

where

Pn : number of pole pairs
ψa : interlinkage magnetic flux
Ld : d-axis inductance
Lq : q-axis inductance
Iq : q-axis current
Id : d-axis current

Formula (1) shows a voltage equation of dp conversion. For example, in a surface magnet motor, since the permeability of permanent magnet is nearly equal to that of air, both inductance Ld and Lq in formula (1) are nearly equal values, and the reluctance torque portion expressed in the second term enclosed in braces in formula (1) does not occur.

In addition to the magnet torque, by utilizing the reluctance torque, if desired to increase the torque of the driving motor, according to formula (1), it is enough to increase the difference of (Ld-Lq). The inductance L, which expresses the degree of ease of passing of magnetic flux, is proportional to N^2 (number of turns of teeth) , and hence by increasing the number of turns on the teeth, the difference of (Ld-Lq) becomes larger, so that the reluctance torque can be increased. However, if the number of turns is increased in order to utilize the reluctance torque more, as the number of turns increases, the winding group projecting to the stator end surface, that is, the coil end becomes larger. Hence, to rotate and drive the motor efficiently, if attempted to make use of the reluctance torque, the coil end becomes larger, and the motor itself is increased in size.

In the distributed winding, moreover, by turning windings plural times, a winding ring is formed, and this winding ring is inserted into teeth, and the periphery of the winding ring becomes longer than the periphery of teeth. Still more, in the distributed winding, since the teeth are wound through slots, the windings cross each other. Thus, in the distributed winding, the winding projects from the stator end, and the windings cross each other to increase the size of the coil end.

Hence, if attempted to drive the motor efficiently by making use of the reluctance torque, the motor size becomes larger. To the contrary, if the motor is reduced in size, the output of the motor drops.

In the air-conditioner, refrigerator, electric vehicle, etc., however, a motor of large output and small size is required.

Incidentally, the magnetic pole portion at the end of teeth in the stator is formed wider in the peripheral direction. Between the adjacent magnetic pole portions, however, since openings are formed for laying down windings in the slots, the interval of ends of teeth must be formed wider in the peripheral direction. That is, because of the distributed winding, an opening for inserting the winding ring in the teeth is needed. Incidentally, the gap between the stator inner circumference and the rotor outer circumference is generally set uniform on the whole periphery except for the openings of the slots.

In such conventional constitution, at the stator side, since there is an opening for a slot between magnetic pole portions, an insulating portion in the peripheral direction is formed in the distribution of the magnetic flux leaving the magnetic pole portions, which produced a problem of occurrence of cogging torque during rotor rotation. At the rotor side, when the distribution of the magnetic flux leaving its outer circumference is brought closer to sine waveform, the cogging torque can be decreased, but since the gap between the stator inner circumference and rotor outer circumference is uniform, the magnetic resistance in this gap is constant on the whole periphery, and in the joining portions the ends of the permanent magnets, the magnetic flux distribution changes suddenly, and the cogging torque increases. Thus, the cogging torque increasing factors are combined at the stator side and rotor side, and a large cogging torque was caused.

SUMMARY OF THE INVENTION

In the light of the problems of the prior art, it is hence an object of the invention to present a motor of large output and small size, and moreover a motor of small cogging torque.

The motor of the invention comprises a stator core having plural teeth and slots provided among these teeth, a winding making a single turn around the teeth, and a rotor incorporating plural permanent magnets, being constituted to rotate and drive by making use of reluctance torque, in which the winding does not cross because of a single turn, and the coil end can be decreased in size.

Moreover, in the core composed by combining plural independent core elements in an annular form, since the winding is turned in the portion of a slot recess formed at both sides of the teeth of the core element, and the winding is turned in a state of core element, the winding can be applied on the stator in neat arrangement. Moreover, since the winding is not turned in the adjacent state of teeth, it is not necessary to keep a wide opening between the ends of teeth, so that the interval of ends of teeth can be narrowed.

Further, in the stator core composed by coupling ends of plural core elements, and folding the core element group with bent ends into an annular form, since the winding is turned in the slot shape recess portion formed at both sides of the teeth of the core elements , when winding around the teeth, the end interval of teeth can be widened, and the winding can be applied around the teeth in neat arrangement. Moreover, since the ends are coupled, position setting when assembling is easy.

Further, the clearance between the confronting surface of teeth of the permanent magnet and the outer circumference of the rotor core is wider in the central part than in the end portion of the permanent magnet, and the reluctance torque can be utilized effectively.

Further, since the shape of the permanent magnet is projecting toward the center of the rotor in its middle, the reluctance torque can be utilized effectively.

Further, since the width between the adjacent permanent magnets is 0.15 to 0.20 of the width of teeth confronting two magnetic poles (two permanent magnets), the torque ripple of the motor can be suppressed.

Further, the leading end of the magnetic pole portion of the inner circumferential side of the teeth is projecting in the peripheral direction across a slight gap between the ends of teeth, and the gap between the teeth and rotor outer circumference is nearly constant, so that useless magnetic flux does not flow at the ends of teeth.

Further, as the leading end of the magnetic pole portion of the inner circumferential side of the teeth is projecting in the peripheral direction so as to connect between ends of the teeth, the gap between the teeth and rotor outer circumference may be continuous.

Further, by setting the width b of the opposite sides of the ends of teeth at $b < 0.6$ mm, the magnetic flux is saturated at the ends of the teeth.

Further, the incorporated permanent magnets are thinner in thickness of the permanent magnet positioned ahead in the rotor rotating direction than in the thickness of the permanent magnet rear portion, so that the quantity of the permanent magnets may be decreased without lowering the torque.

Further, the profile of the adjacent portions of the permanent magnets is a recess form corresponding to the disk-shape profile positioned outside of the center of the permanent magnet, and the magnetic resistance is increased in the adjacent portions of the permanent magnets, so that the magnetic flux distribution may be close to a sine waveform.

Further, the length of the rotor outer recess positioned outside of the adjacent portions of the permanent magnets should be properly corresponding to the angle of 0.2 to 0.4 of the central angle of the one pole portion of the rotor core.

Further, the gap between the rotor outer recess and teeth should be properly two times or more of the gap between the rotor outer circumference and the teeth.

Further, when the incorporated permanent magnets have two layers, the q-axis inductance increases, and the reluctance torque portion is maximized.

Further, the interval is properly a value set larger than 1/3 of the width of the teeth.

Further, when the winding is a flat square wire, the occupation rate can be enhanced than in the case of round wire. In particular, the winding of flat square wire is suited to concentric concentrated winding around the teeth.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a sectional view of a motor in embodiment 1 of the invention, Fig. 2 is a partial sectional view of a stator in embodiment 1, Fig. 3 is a partial sectional view of a rotor in embodiment 1, Fig. 4 is a diagram showing a core element of embodiment 1, Fig. 5 is a sectional view of a motor in embodiment 2 of the invention, Fig. 6 is a sectional view of a motor in embodiment 3 of the invention, Fig. 7 is a sectional view of a motor in embodiment 4 of the invention, Fig. 8 is a sectional view of a motor in embodiment 5 of the invention, and Fig. 9 is a partial sectional view of a core element group in embodiment 5.

BEST MODE FOR CARRYING OUT THE INVENTION

Referring now to Fig. 1 through Fig. 4, embodiment 1 of the invention is described below.

In Fig. 1, reference numeral 1 is a synchronous motor which rotates by utilizing reluctance torque, as well as magnet torque, and it is composed of a stator 2, a rotor 3, and a rotary shaft 4.

The stator 2 is composed of a ring-shaped frame

individually, a winding applied on the teeth by a single turn, and a rotor incorporating plural permanent magnets.

2. A motor rotating and driving by utilizing reluctance torque, comprising a stator core having plural teeth and slots provided among teeth of said plural teeth individually, a winding applied on the teeth by a single turn, and a rotor incorporating plural parts of low permeability.

3. A motor of claim 1, wherein said stator core composed by combining plural independent core elements in an annular form has said winding turned in the slot shape recess formed at both sides of the teeth of the core elements.

4. A motor of claim 1, wherein said stator core composed by coupling end portions of plural core elements, and folding the core element group having bending ends in an annular form has said winding turned in the slot shape recess formed at both sides of the teeth of the core elements.

5. A motor of claim 1, wherein said stator core composed by combining plural sets of core element groups coupling the end portions of plural core elements, and folding in an annular form has said winding turned in the slot shape recess formed at both sides of the teeth of the core elements.

6. A motor of claim 1, wherein the interval between the teeth confronting surface of the permanent magnets and the core outer circumference of said rotor is wider in the middle part than at the end portions of the permanent magnets.

7. A motor of claim 6, wherein the shape of said permanent magnets is formed in a flat plate.

8. A motor of claim 6, wherein the shape of said permanent magnets projects toward the center of the rotor in the middle.

9. A motor of claim 8, wherein the shape of said permanent magnets is in a V-form.

10. A motor of claim 8, wherein the shape of said permanent magnets is in an arc form.

11. A motor of claim 1, wherein the width of said adjàcent permanent magnets is in a range of 0.15 to 0.20 to the width of teeth confronting to two magnetic poles.

12. A motor of claim 1, wherein the ends of magnetic poles at the inside of said teeth project in the peripheral direction across a slight interval between ends of said teeth.

13. A motor of claim 12, wherein the slight interval d between ends of said teeth is in a range of $0 < d < 0.2$ mm.

14. A motor of claim 1, wherein the ends of magnetic poles at the inside of said teeth project in the peripheral direction so as to connect between the ends of said teeth.

15. A motor of claim 14, wherein the width b of the confronting surface of the ends of said teeth is in a range of $b < 0.6$ mm.

16. A motor of claim 6, wherein said incorporated permanent magnets are greater in thickness in the permanent magnet backward portion positioned behind in the rotor rotating direction than in the permanent magnet forward portion.

17. A motor of claim 16, wherein the shape of said permanent magnets is in a V-form projecting toward the rotor center.

18. A motor of claim 16, wherein a weight for adjusting the balance of said incorporated permanent magnets is buried in the rotor.

19. A motor of claim 1, wherein the outline of adjacent portion of said plural permanent magnets is in a convex form to the outline of the circular shape positioned outside of the middle of said permanent magnets.

20. A motor of claim 19, wherein the outer circumference of said rotor positioned outside of the adjacent portion of said permanent magnets is a linear outer circumferential section of the rotor.

21. A motor of claim 19, wherein the length of outer circumferential concave portion of said rotor positioned outside of the adjacent portion of said permanent magnets corresponds to an angle of 0.2 to 0.4 of the central angle of one pole of the rotor core.

22. A motor of claim 19, wherein the interval of the outer circumferential concave portion of said rotor and said teeth is more than two times the interval of the outer circumference of said rotor and said teeth.

23. A motor of claim 19, wherein the width of the interval of the outer circumferential concave portion of said rotor and said teeth is in a range of 0.7 to 1 mm.

24. A motor of claim 8, wherein said incorporated per-

manent magnets are formed in plural layers.

25. A motor of claim 24, wherein said incorporated permanent magnets are formed in two layers.

26. A motor of claim 25, wherein the interval of said outside permanent magnet and said inside permanent magnet is a constant interval.

27. A motor of claim 26, wherein the interval is set larger than 1/3 of the width of teeth.

28. A motor of claim 1, wherein said winding is a flat square wire.

29. A motor of claim 28, wherein the section of said flat square wire is 4 mm or more in width and 1.5 mm or more in height.

30. A motor of claim 1, wherein said motor is rotated and driven at 300 amperes or more.

31. A compressor employing a motor of claim 1.

32. An electric vehicle employing a motor of claim 1.

33. An air-conditioner employing a motor of claim 1.

34. A refrigerator employing a motor of claim 1.

Fig. 1

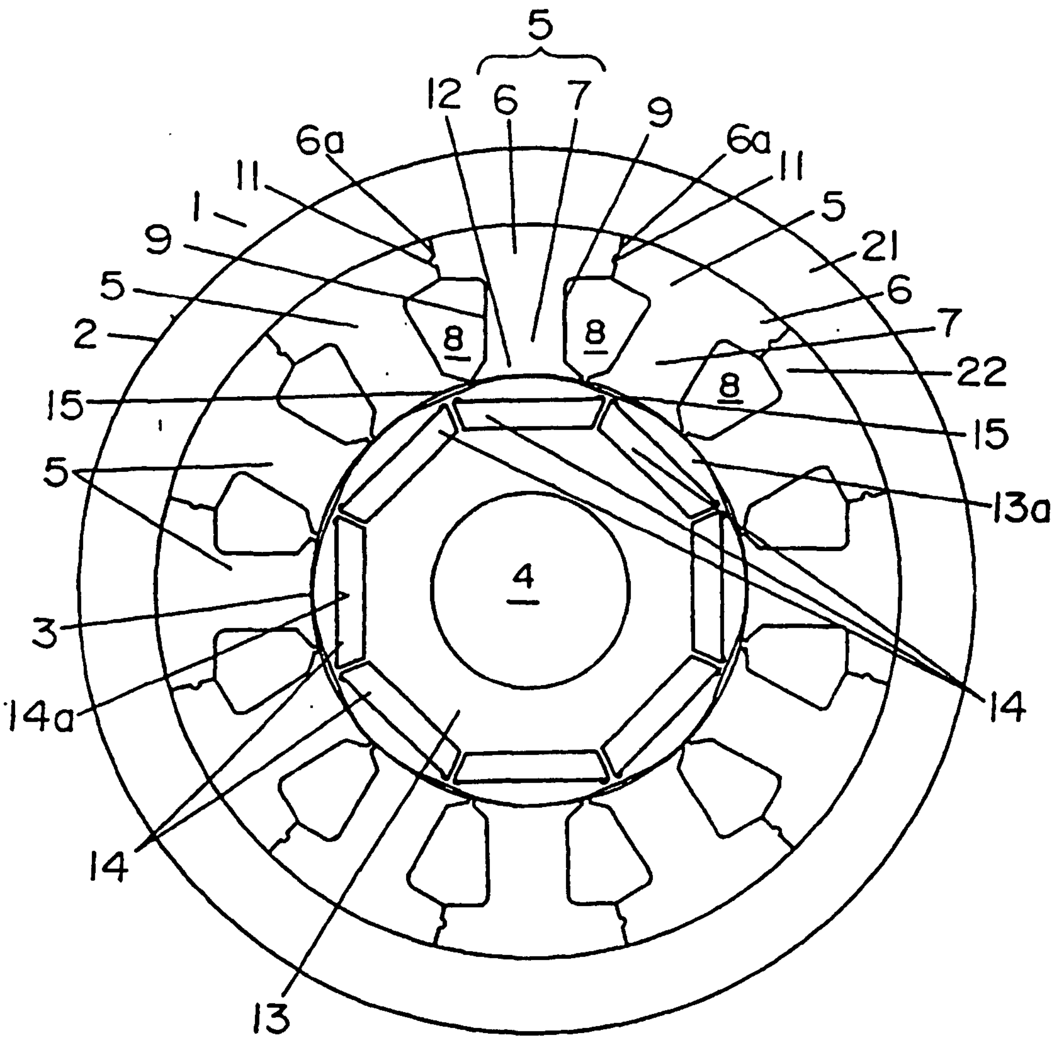
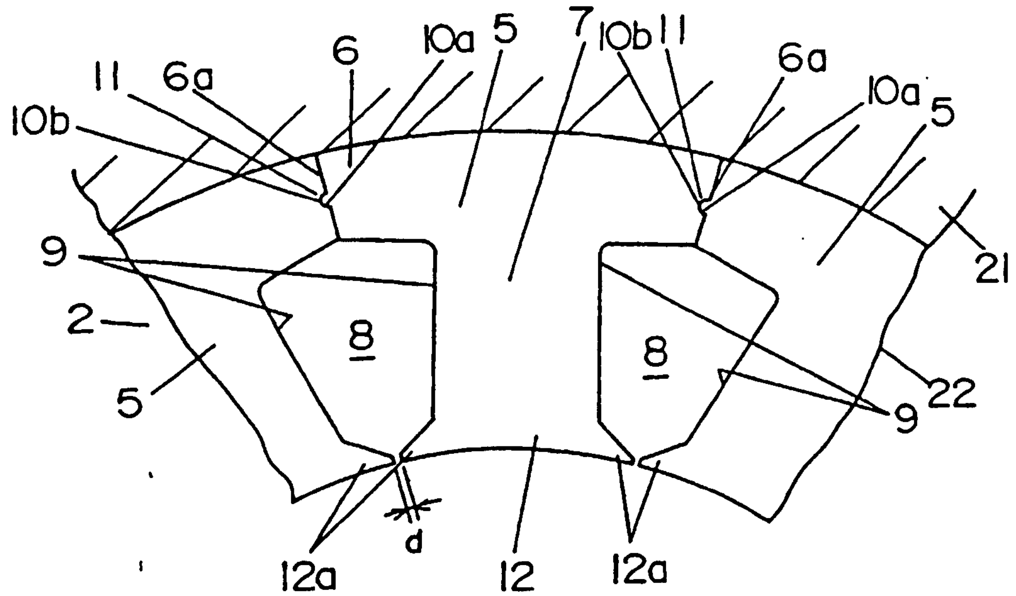


Fig.2


11
6a
6
10a
5
7
10b
11
6a
10a
5
10b
9
2
5
8
8
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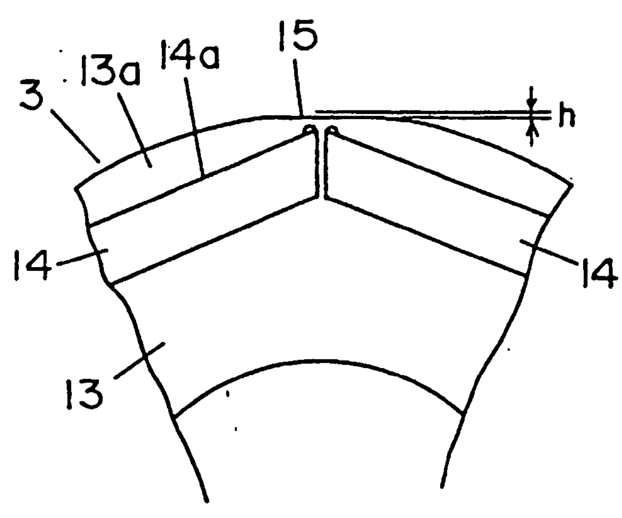
22
9
12a
d
12
12a

Fig.3


3
13a
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14
13

Fig.4

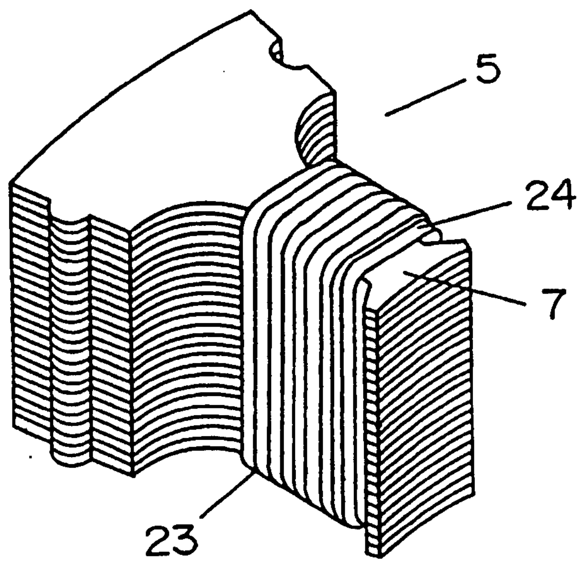


Fig.5

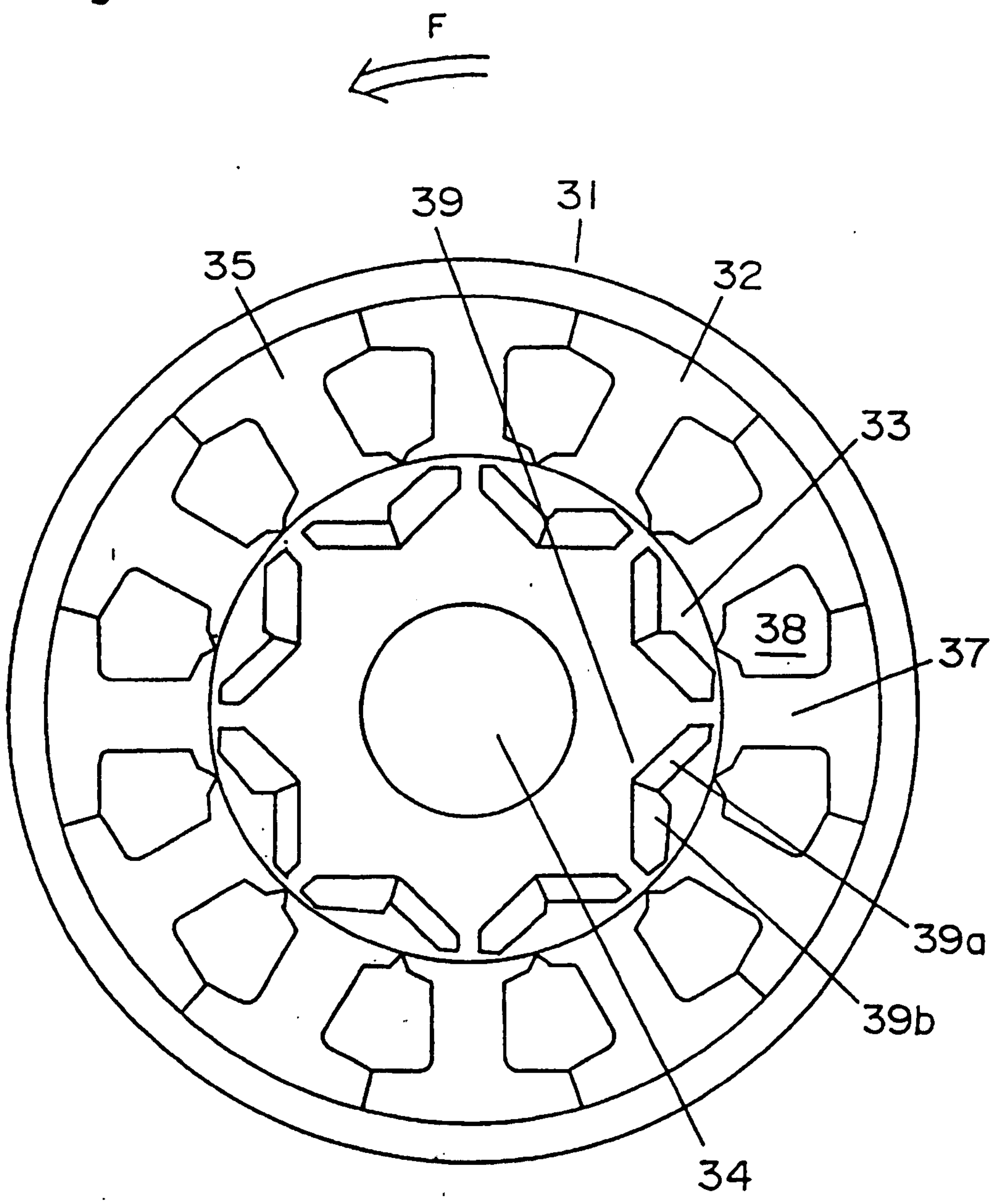


Fig.6

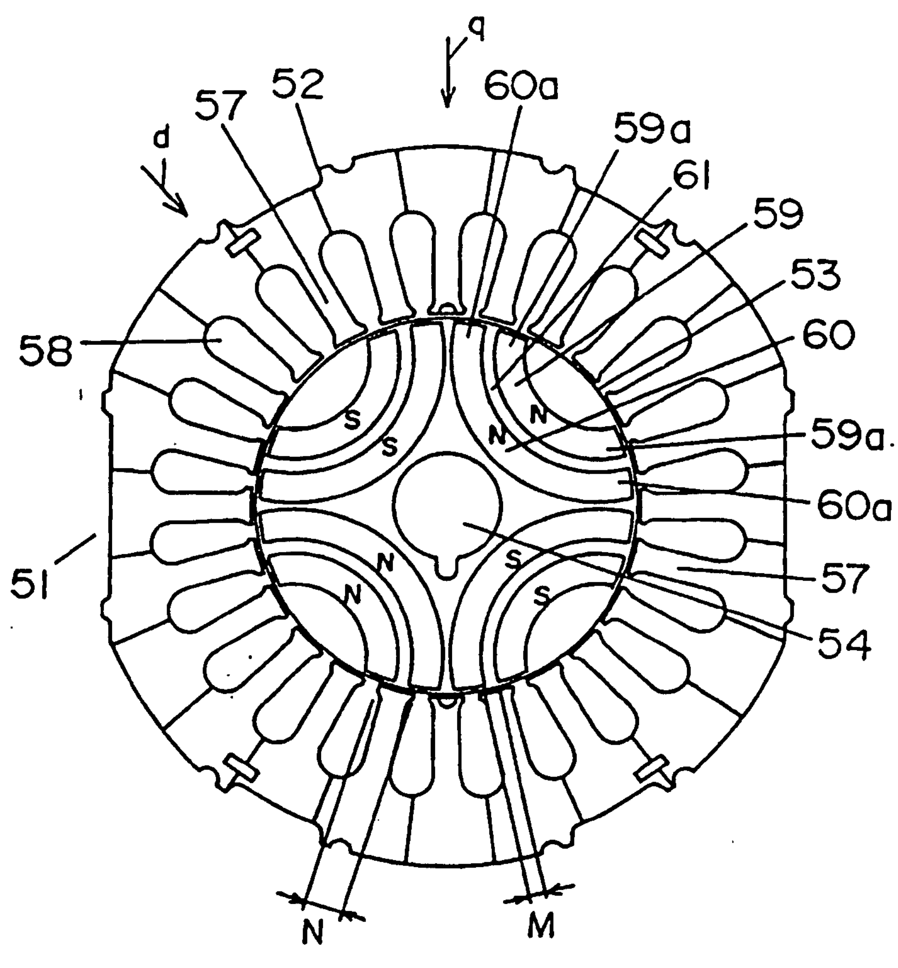


Fig.7

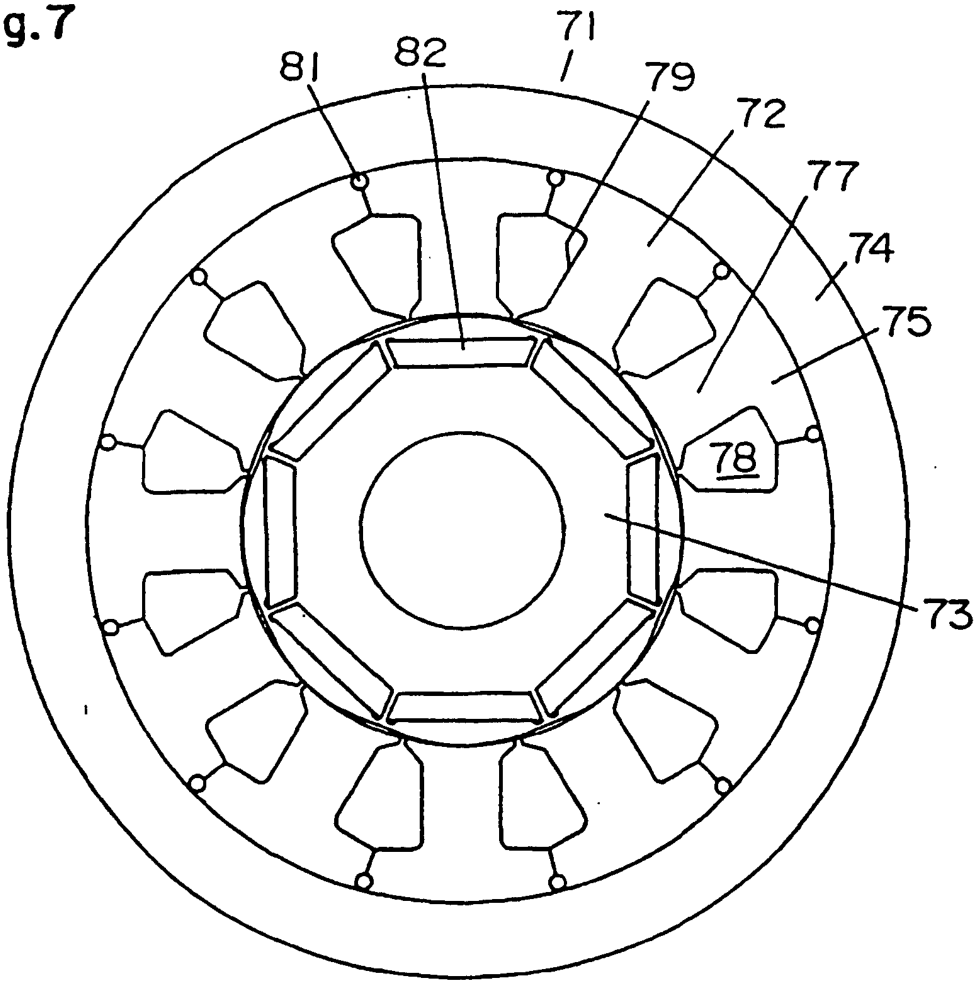
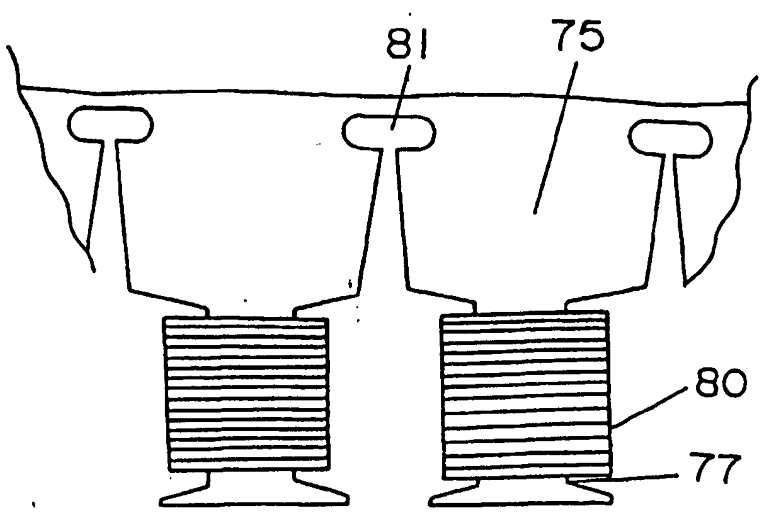


Fig.8



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP97/00489

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl^6 H02K21/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int. Cl^6 H02K21/14-21/16, H02K1/14-1/16, H02K1/27, H02K19/02-19/14, H02K29/00-29/14

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1926 - 1997
Kokai Jitsuyo Shinan Koho	1971 - 1996
Toroku Jitsuyo Shinan Koho	1994 - 1997

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP, 7-255138, A (Yaskawa Electric Corp.), October 3, 1995 (03. 10. 95), Claim 1; column 2, lines 43 to 47 (Family: none)	1, 3, 6, 11-13, 15, 30-34
Y		2, 4, 5, 7, 8-10, 14, 19-29
Y	JP, 7-303357, A (Okuma Corp.), November 14, 1995 (14. 11. 95), Column 5, lines 17 to 21; Fig. 8 (Family: none)	2
Y	JP, 5-292714, A (Mitsubishi Electric Corp.), November 5, 1993 (05. 11. 93), Column 3, lines 1 to 9; Fig. 3 (Family: none)	4, 5
Y	JP, 8-19196, A (Mitsubishi Electric Corp.), January 19, 1996 (19. 01. 96), Column 21, lines 22 to 36; Figs. 1, 2, 6, 7 (Family: none)	4, 5

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
May 20, 1997 (20. 05. 97)	May 27, 1997 (27. 05. 97)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP97/00489

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP, 7-20050, U (Yaskawa Electric Corp.), April 7, 1995 (07. 04. 95), Figs. 1, 4, 5 (Family: none)	7 - 10
Y	JP, 5-284677, A (Yaskawa Electric Corp.), October 29, 1993 (29. 10. 93), Fig. 1 (Family: none)	14
Y	JP, 7-236240, A (Sanyo Electric Co., Ltd.), September 5, 1995 (05. 09. 95), Fig. 4 (Family: none)	19 - 23
Y	JP, 6-66277, U (Yaskawa Electric Corp.), September 16, 1994 (16. 09. 94), Figs. 2, 4 (Family: none)	24 - 27
Y	JP, 62-160048, A (Shinko Electric Co., Ltd.), July 16, 1987 (16. 07. 87), Claim 1; Fig. 1 (Family: none)	28, 29

Form PCT/ISA/210 (continuation of second sheet) (July 1992)